

# DISTRIBUTION OF SPORE AND POLLEN ASSEMBLAGES IN THE LOWER KITTANNING COAL OF WESTERN PENNSYLVANIA

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**ABSTRACT.** Palynological study of the Lower Kittanning coal seam of western Pennsylvania (Allegheny Series; lower Westphalian D) has revealed an orderly vertical and geographical distribution of spore and pollen assemblages.

Assemblages characterized by *Densosporites* and *Punctatisporites* (*P. obliquus*) occur in the uppermost zones where the seam is directly overlain by marine and restricted-marine faunal facies, respectively, of the Lower Kittanning shale. The greatest vertical variation of assemblages occurs at these localities. Where the seam is in direct contact with the overlying freshwater facies, however, it remains dominated throughout its thickness by assemblages rich in *Lycospora*. Fewer assemblages occur at these localities. Because of the distribution of spore and pollen assemblages in the seam and faunal facies in the overlying shale, a genetic relationship is suggested.

New taxa include two genera, *Spackmanites* and *Paleospora*, and thirty-three species.

THE Lower Kittanning coal seam in western Pennsylvania is one of the more readily identifiable and geographically extensive stratigraphic horizons of the Allegheny Series (middle Pennsylvanian age). Because it is easily recognized, variations in the biological, physical, and chemical properties of the seam and surrounding rocks have been investigated. The known variation in these properties has prompted investigation of the seam once again, this time to determine the vertical and geographic distribution of its spore and pollen assemblages. It was assumed at the beginning of this study that if distinctive spore and pollen assemblages at least partially represent *in situ* Lower Kittanning plant communities, then some distributional pattern of their assemblage zones should be discernible, in light of the known distributional pattern of other properties in the seam and juxtaposed rocks.

*Methods of study.* Vertical columns of the Lower Kittanning seam were collected from 15 localities in the western part of the state (text-fig. 1). A one-inch increment of coal was taken at three-inch levels in sequence in each column from the top downward. Where the bottom-most sample did not coincide with this interval, it was taken as an additional sample. The density of sampling sites was intended to cover a large area while keeping the geographic interval small.

Maceration of the samples consisted of oxidation in nitric acid or Schulze's solution, and subsequent treatment in 8% potassium hydroxide. The spore residue was then mounted on slides in glycerine jelly. Two hundred specimens were counted from each sample (100 per slide). The entire slide was examined at  $\times 100$  and/or  $\times 450$  magnification, in order to determine the total number of species per sample.

*Geological setting.* The Kittanning formation comprises the middle third of the Allegheny Series (Westphalian C-D). The formation is defined by three major coal horizons which are separated by two thicker and lithologically more variable detrital units. The lowermost coal seam, the Lower Kittanning, is overlain by the Lower Kittanning

shale, a unit which separates the seam from the next overlying coal horizon by an interval of from 30 to 50 ft.

On the basis of the distribution of fossil invertebrates in the Lower Kittanning shale, Williams (1959) differentiated facies depicting marine, restricted-marine, and fresh-water environments of deposition. In a northwesterly direction across the sedimentary strike of the marine embayment, the fresh-water facies of the Lower Kittanning shale, represented by estherids, changes to restricted-marine (*Lingula*, *Aviculopecten*), and marine (*Mesolobus*, other calcareous brachiopods, gastropods) facies in respective order, before reverting through restricted-marine and fresh-water facies. Geochemical evidence corroborates the delimitation of marine and fresh-water facies. Degens *et al.* (1957, 1958) distinguished these facies by relative abundance of trace element assemblages. Greater concentrations of boron and rubidium were found in the marine shales, while gallium was found to be more abundant in the fresh-water shales. Williams and Keith (1963) subsequently showed a statistical relationship between the sulphur content of the seam and the facies of the directly overlying rocks (Lower Kittanning shale), the content being higher in the seam where it directly underlies ancient marine sediments. Weber *et al.* (1964) distinguished fresh-water siderite nodules in the Lower Kittanning shale from marine nodules through distinct differences in their carbon isotope ratios.

#### *Sampling Sites*

*Station 1.* Section exposed in a limestone quarry, 7 miles west of New Castle, Pennsylvania. The Vanport limestone is mined here and is exposed approximately 40–50 ft. below the Lower Kittanning seam. Marine shale overlies the seam, characterized by *Lingula* and *Mesolobus*.

*Station 2.* Section exposed in coal strip pit, 1 mile east of West Pittsburg, Pennsylvania. The seam is slightly thicker than that reported for the Lower Kittanning in this area.

*Station 3.* Section exposed in a road cut, on the east side of a toll bridge, 1 mile E. of Freedom, Pennsylvania. The marine facies of the Lower Kittanning shale is represented here by *Mesolobus*.

*Station 4.* Section exposed in a coal strip pit, 5 miles north-west of Harlansburg, Pennsylvania. The Lower Kittanning shale is characterized here by sandstone beds occurring 10 ft. above the seam.

*Station 5.* Section exposed in coal strip pit, 4 miles west of Slippery Rock, Pennsylvania. Plant remains prevail in the nonmarine facies of the Lower Kittanning shale. Sandstone beds occur 6 ft. above the seam.

*Station 6.* Section exposed in road cut 1 mile east of Nectarine, Pennsylvania. Thin irregularly bedded sandstone, with plant remains, lies just above the seam.

*Station 7.* Section exposed in strip pit, 1 mile north-north-west of West Freedom, Pennsylvania. The Vanport limestone is exposed approximately 40–50 ft. below the seam. The shale is characterized by interlaminated light and dark layers (varves), with abundant plant fragments.

*Station 8.* Type locality of the seam. Section exposed in a railroad cut above west bank of Allegheny River, outside of Kittanning, Pennsylvania. *Mesolobus* occurs in the shale a few inches above seam.

*Station 9.* Section exposed in strip pit 1 mile east of Turkey City, Pennsylvania. The Vanport limestone is exposed approximately 25 ft. below the seam.

*Station 10.* Section exposed in strip pit, on a hill 2 miles west of U.S. Route 68, and 15 miles south of Clarion, Pennsylvania. *Mesolobus* abounds in the upper portions of the shale, with *Lingula* just above the seam. Shale is interlaminated in the lower part.

*Station 11.* Section exposed in strip pit 2 miles south of Limestone, Pennsylvania. The shale contains *Lingula*.

*Station 12.* Section exposed in strip pit 1 mile west of Truittsburg, Pennsylvania. The shale contains abundant *Mesolobus* a few inches above the seam. The seam varies within the pit from 64 to 38 ins. in thickness, through a distance of 100 ft.

*Station 13.* Section exposed in road cut on north side of creek, just north of Worthville, Pennsylvania. *Lingula* occurs just above the seam, with *Mesolobus* predominant above.

*Station 14.* Section exposed in strip pit 0.25 miles north-east of Hamilton, Pennsylvania. *Aviculopecten* and *Lingula* are present just above the seam, with *Mesolobus* and other calcareous brachiopods prevalent above.

*Station 15.* Section exposed in strip pit 1 mile south of Curwensville, Pennsylvania. *Lingula* and *Aviculopecten* occur in the shale.

#### SYSTEMATIC DESCRIPTIONS

One hundred and forty species of spores and pollen, situated in 59 genera, were recognized. Of these 33 are formally described as new, and 14 are given lettered specific designations due to insufficient number of specimens. Two new genera, *Spackmanites* and *Paleospora*, are proposed. All slides used in this study are stored in the Organic Sediments Laboratory, The Pennsylvania State University. Position of specimens on the slides is indicated by the scale settings of an E. Leitz ortholux microscope, serial no. 448497. All measurements are given with reference to the maximum diameter of specimens. Wherever possible, holotypes were mounted as single grain wax mounts.

Anteturma SPORONITES (R. Pot.) Ibr. 1933

Genus RETICULATASPORITES Leschik 1955

*Reticulatasporites aletoreticulus* sp. nov.

Plate 104, fig. 1

*Diagnosis.* Alete spores; subcircular to circular in outline. Exine covered with concentric reticulation pattern; lacunae largest in centre and become smaller and more lenticular towards margin, as well as more low-lying; muri conversely become wider and more low-lying towards margin, eventually grading into exine. No evidence of tetrad scar. Exine approximately 1.5–2.0  $\mu$  thick. Size range (twelve specimens) 53 to 66  $\mu$ .

*Holotype.* Plate 104, fig. 1; 53  $\times$  55  $\mu$ ; slide LKC-2 (27–28) 1, coordinates 24.3 127.7.

*Remarks.* Spores of this species are characterized by the marginward diminution of its reticulate pattern. The species was observed only at Station 2, where it is confined to samples containing the *Lycospora-Guthoerlisporites erectus* assemblage. *Reticulatasporites aletoreticulus* sp. nov. resembles the detached caps of specimens of *Vestispora*, but could be distinguished in the Lower Kittanning seam by its larger size and ornamental pattern.

Anteturma SPORITES H. Pot. 1893

Turma TRILETES Reinsch 1881

Subturma AZONOTRILETES Lubert 1935

Infraturma LAEVIGATI (Benn. and Kidst.) R. Pot. 1956

Genus LEIOTRILETES Naumova ex Pot. and Kr. 1954

*Leiotriletes* sp. A

Plate 104, figs. 2, 3

*Description.* Trilete spores; triangular, with sharply rounded radial corners and concave or slightly convex (due to folding) inter-radial margins. Exine one micron thick or less; essentially levigate. Trilete mark distinct and slightly raised; it extends almost to radial corners; contact area defined by faintly sinuous ('wrinkled') curvaturae which turn

in inter-radially toward juncture of sutures. Two specimens,  $41 \times 41 \mu$ , and  $36 \times 38 \mu$  (folded).

*Remarks.* Shape and thickness of spore coat relate the two specimens to *Leiotriletes ornatus* Naum. and *L. tumidus* Butt. and Will. They are distinguished, however, by their unique curvaturae. The specimens were observed only at Stations 5 and 7; both are present in zones containing the *Thyuspora pseudothiesseni* assemblage.

Genus CALAMOSPORA S. W. and B. 1944

*Calamospora multiplicata* sp. nov.

Plate 104, figs. 6, 7

*Diagnosis.* Trilete spores; roundly elliptical in outline. Exine smooth, one micron thick or less. From 3 to 9 curving, slender folds criss-cross exine in concentric and radial directions; they are typically long and slender. Trilete mark short, extending less than one-half radius; lips very thin and only slightly raised; contact area present, but only slightly darker than remaining exine. Size range (twenty-five specimens)  $43\text{--}60 \mu$ .

*Holotype.* Plate 104, fig. 6;  $55 \times 41 \mu$ ; slide LKC-10 (13-14) 2, 43.9 113.9.

*Remarks.* *Calamospora multiplicata* sp. nov. is present at every locality; it is most common in the *Thyuspora pseudothiesseni* and *Lycospora-Guthoerlisporites erectus* assemblages. The species is distinguished from other species of *Calamospora* in the Lower Kittanning seam by its size, roundly elliptical outline, and disposition of folds.

*Calamospora elliptica* sp. nov.

Plate 104, figs. 9, 10

*Diagnosis.* Trilete spores; elliptical to subelliptical-elongate in both polar and equatorial views. Exine not over  $1.5 \mu$  thick; generally smooth, although the slightly darker contact area may be slightly pitted; contact area not delimited by any specialized curvaturae. Secondary folds always present, usually grouped near margin; relatively long, slender,

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EXPLANATION OF PLATE 104

All figures  $\times 500$ .

Fig. 1. *Reticulatasporites aletoreticulus* sp. nov., holotype.

Figs. 2-3. *Leiotriletes* sp. A.

Figs. 4-5, 8. *Calamospora pseudotriangulara* sp. nov. 4, Holotype. 5, Proximal polar view with well-developed contact area. 8, Thin dark folds attending the sutures prominent.

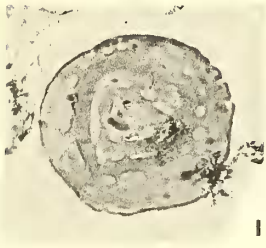
Figs. 6-7. *Calamospora multiplicata* sp. nov. 6, Holotype; slightly corroded but shows short trilete mark and contact area. 7, Specimen with open trilete mark but which shows typical orientation of folds.

Figs. 9-10. *Calamospora elliptica* sp. nov. 9, Holotype; thick lips border trilete mark. 10, Equatorial view.

Figs. 11-14. *Punctatisporites obliquus* Kos.; note size variation, and nature of trilete mark.

Figs. 15, 18. *Punctatisporites globulosus* sp. nov. 15, Holotype; lines of weakness extend longitudinally from sutures on to distal surface. 18, Ruptured specimen, with triangular gap which extends to distal hemisphere.

Figs. 16-17. *Punctatisporites sphaerorigidus* sp. nov. 16, Holotype; thick irregular fold on distal surface. 17, Specimen with T-shaped trilete mark.



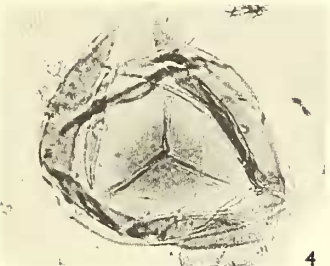
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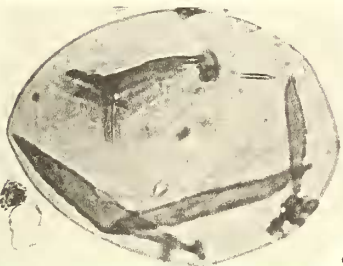
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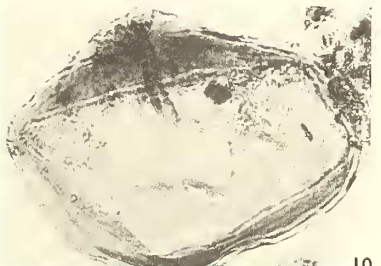
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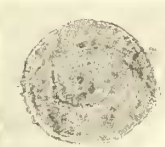
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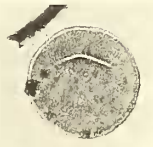
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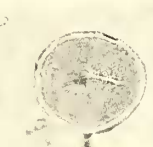
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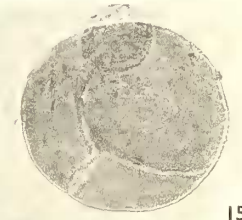
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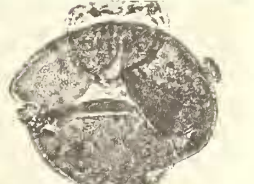
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16



17



18



and smoothly tapering. Trilete mark distinct, extends about one-half radius bordered by thick, raised lips. Size range (ten specimens) 80–100  $\mu$ .

*Holotype*. Plate 104, fig. 9; 85  $\times$  65  $\mu$ ; slide LKC-10M-4, 37.7 128.5.

*Remarks*. The elliptical outline, long slender folds, and short thickly bordered trilete mark distinguish this species.

*Calamospora pseudotriangulara* sp. nov.

Plate 104, figs. 4–5, 8

*Diagnosis*. Trilete spores; subcircular to triangular in polar view, the outline appearing triangular because of the large folds. Trilete mark distinct, extends from one-half to two-thirds radius; thin but dark and distinct folds border it; contact area present, barely discerned to very distinct. Large sharply tapering folds run peripherally and often, because of their orientation, make the species appear triangular; largest peripheral folds most often occur inter-radially. Exine less than one micron thick, levigate. Size range (twenty specimens) 63–82  $\mu$ .

*Holotype*. Plate 104, fig. 4; 75  $\times$  63  $\mu$ ; slide LKC-8 (36–37) 1, 30.2 127.1.

*Remarks*. The species is most common in the upper half of zones containing the *Lycospora-Guthoerlisporites erectus* assemblage. It was not found at Station 13. *Calamospora pseudotriangulara* sp. nov. is easily distinguished from other related species by its size, triangular outline, thin exine, and long sutures bordered by thin, distinct folds.

Genus PUNCTATISPORITES Ibr. emend. Pot. and Kr. 1954

*Punctatisporites obliquus* Kosanke

Plate 104, figs. 11–14

*Remarks*. Because a very close relationship was observed between this species and *Laevigatosporites globosus* Schem., they were counted together. Except for only a slight difference in size ranges, the two species are very similar, and perhaps should be conspecific. The true nature of the suture in either species is in doubt. Schemel (1951, p. 747) noted the similarity between the species and admitted that if the nature of the suture could not be determined, it would be doubtful to which species and genus the specimens belong.

*Punctatisporites sphaerorigidus* sp. nov.

Plate 104, figs. 16, 17

*Diagnosis*. Trilete spores; circular to subcircular in outline, occasionally appearing obliquely compressed, due to the presence of a thick fold. Exine generally smooth, but may be irregularly pitted in localized areas; up to 5–6  $\mu$  thick in polar view. Trilete mark distinct and frequently open, extends about one-half radius or less; lips present but only slightly raised; occasionally the trilete mark assumes a T-shape. Single large compression fold, in some specimens accompanied by a smaller fold, usually present, restricted to distal hemisphere. Size range (twenty-five specimens) 75–98  $\mu$ .

*Holotype*. Plate 104, fig. 16; 83  $\times$  74  $\mu$ ; slide LKC-2 (12–13) 1, 22.1 123.4.

*Remarks.* The species rarely exceeded one per cent in any sample. It was observed most frequently in zones containing the *Punctatisporites obliquus* and *Thymospora pseudothieseni* assemblages. *Punctatisporites sphaerorigidus* sp. nov. is distinguished by its size, thick exine, and relatively short trilete mark. It differs from *P. obesus* (Loose) Pot. & Kr., which also occurs in the seam, by its shorter trilete mark, smaller size, and relatively thicker exine.

*Punctatisporites globulosus* sp. nov.

Plate 104, figs. 15, 18

*Diagnosis.* Trilete spores; elliptical to subcircular in outline. Exine covered over its entire surface by dense, very closely spaced punctae; occasionally, probably due to locally unornamented areas, a few low-lying ( $1\ \mu$  or less) rounded protuberances emerge from the spore outline. Trilete mark distinct, and extends over one-half radius; lips distinct, slightly raised; extending radially from the end of each suture is a thin line along which the spores tend to rupture; ruptured specimens collapse usually to more elliptical outline with opened trilete mark forming triangular outline and extending well on to distal hemisphere. Size range (twenty-five specimens) 45–60  $\mu$ .

*Holotype.* Plate 104, fig. 15;  $56 \times 53\ \mu$ ; slide LKC-6 (15–16) 1, 20-6 118-0.

*Remarks.* The species was most frequently encountered in zones containing the *Punctatisporites obliquus* assemblage, although it rarely exceeded two per cent.

*Punctatisporites globulosus* sp. nov. differs from other species of *Punctatisporites* by its lines of weakness along which the specimens tend to rupture.

*Punctatisporites ellipticus* sp. nov.

Plate 105, fig. 1

*Diagnosis.* Trilete spores; distinctly elliptical in outline. Exine about one micron thick; ornamented with minute but distinct, equidistant punctae which, as seen on the outline, could also be considered coni. Trilete mark distinct; extends from one-half to two-thirds radius; lips thin and slightly upturned. Size range (fifteen specimens) 55–65  $\mu$ .

*Holotype.* Plate 105, fig. 1;  $60 \times 43\ \mu$ ; slide LKC-2 (12–13) 1, 33 113-6.

*Remarks.* This species is similar to *P. globulosus* sp. nov. but differs in its more elliptical outline and trilete mark. It was encountered most frequently in *Punctatisporites obliquus* assemblage zones.

Infraturma APICULATI (Benn. and Kidst.) R. Pot. 1956

Subinfraturma GRANULATI Dyb. and Jach. 1957

Genus GRANISPORITES Dyb. and Jach. 1957

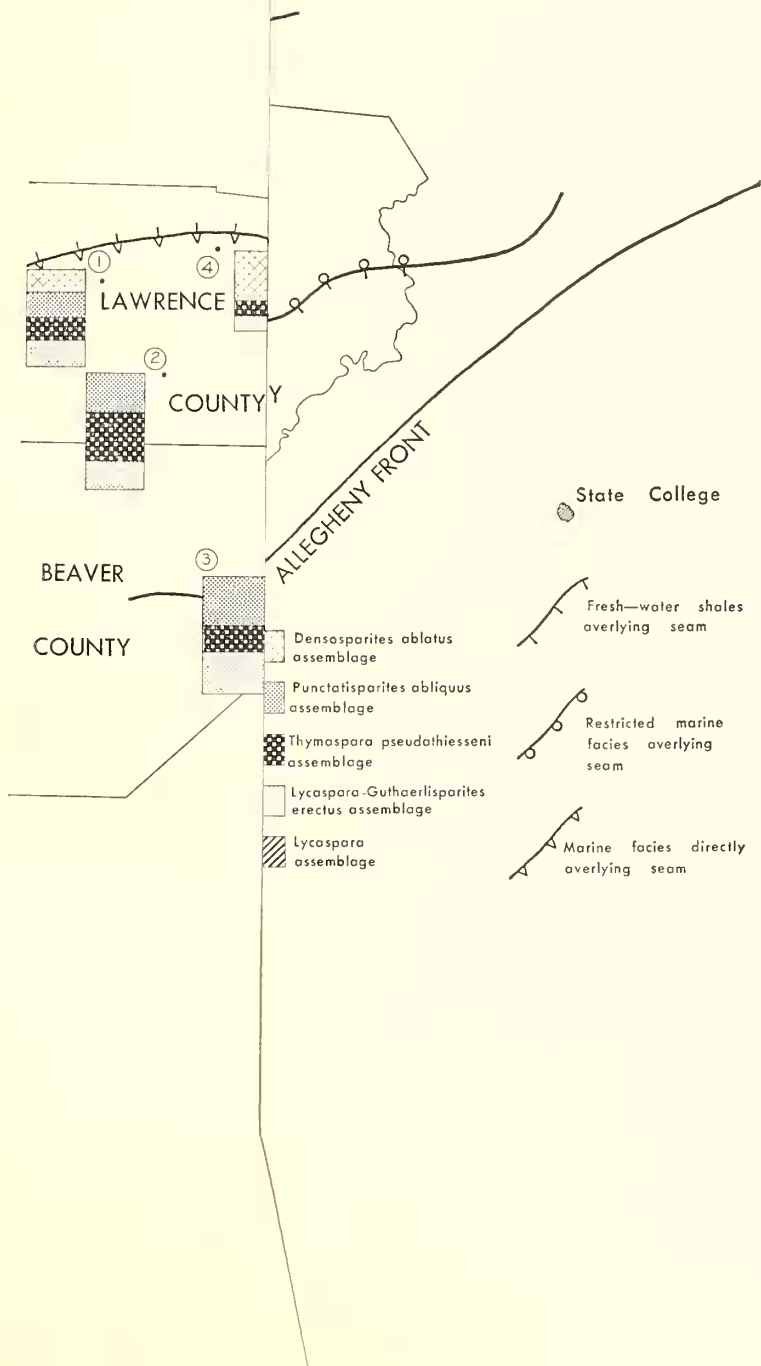
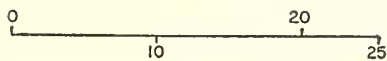
*Granisporites medius* Dyb. and Jach.

Plate 105, figs. 2–3, 5

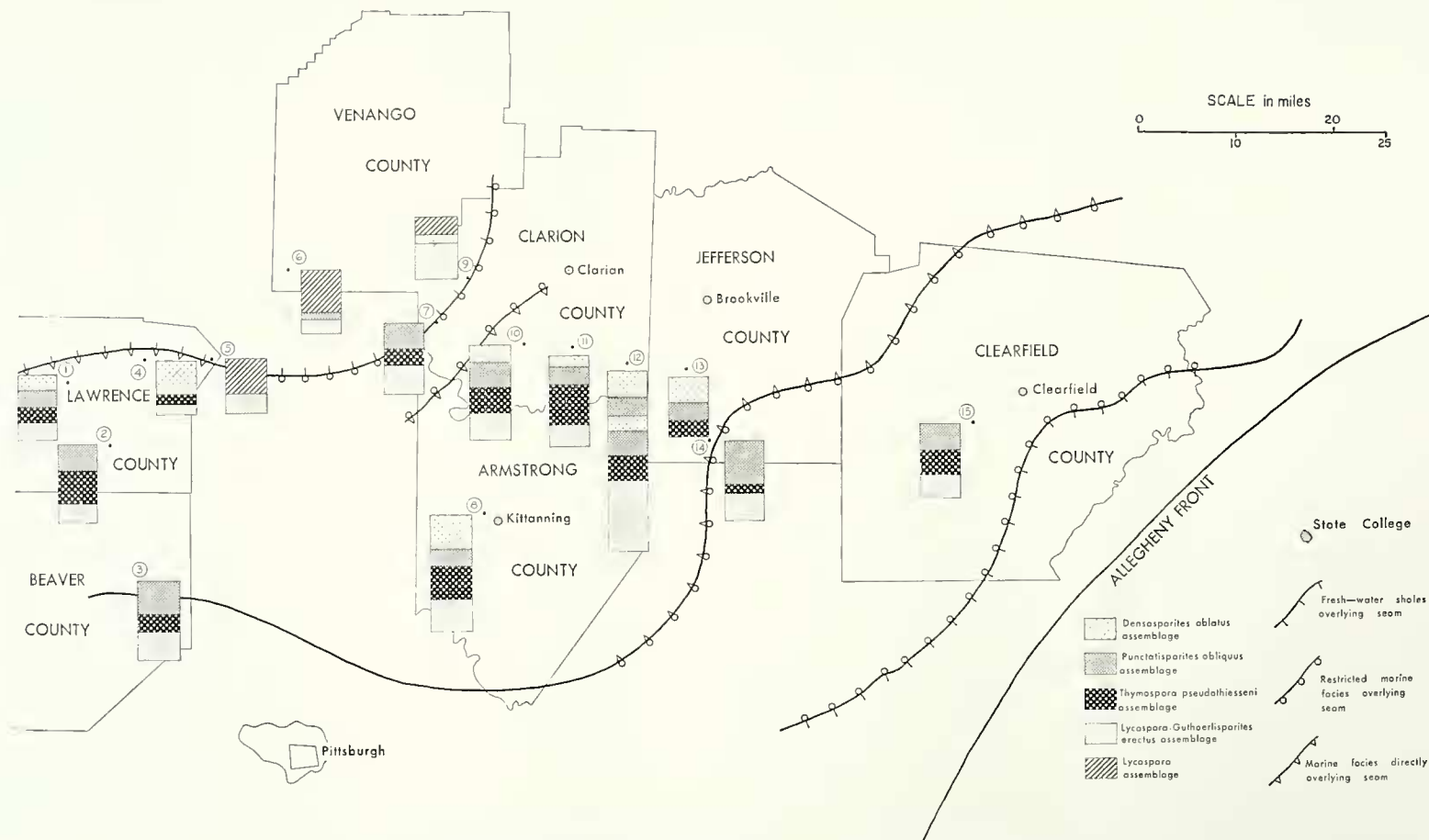
*Remarks.* This species is very similar to those ascribed to *Granisporites* Alpern, the essential difference being the presence of trilete mark in *Granisporites medius*. Occasionally, specimens were observed in tetrads (e.g. Pl. 105, fig. 5).



SCALE in miles







TEXT-FIG. 1. Geographic distribution of spore and pollen assemblages in the Lower Kittanning coal. Faunal facies boundaries from Williams (1959) and Williams and Keith (1963).



Subinfraturma VERRUCATI Dyb. and Jach. 1957

Genus CONVERRUCCOSISPORITES Pot. and Kr. 1954

*Conv verrucosisporites pseudoalvus* sp. nov.

Plate 105, figs. 4, 7

*Diagnosis.* Trilete spores; triangular in polar view, with slightly convex to straight inter-radial margins and subangular to subrounded radial corners. Exine covered with rounded low-lying (approx.  $2\ \mu$  high) verrucae which give the margin a roughened appearance; verrucae all about the same size and evenly distributed, tending, however, to become more numerous and slightly larger at radial corners; occasionally verrucae tend to align themselves concentrically. Trilete mark distinct, extends almost completely to radial corners; lips thin and only very slightly raised. Size range (five specimens)  $38\text{--}50\ \mu$ .

*Holotype.* (Plate 105, fig. 4;  $38 \times 38\ \mu$ ; slide LKC-8 (36-37), wax mount 33.

*Remarks.* Confined to the *Lycospora-Guthoerlisporites erectus* assemblage zones at Stations 8 and 11. *Conv verrucosisporites pseudoalvus* sp. nov. is distinguished from related species by the presence of larger and more numerous verrucae at the radial corners.

Genus SCHOPFITES Kosanke 1950

*Schopfites grossus* sp. nov.

Plate 105, fig. 6

*Diagnosis.* Trilete spores; outline in polar view usually elliptical, but may be near circular. Exine covered subequatorially and distally by short (to  $3\ \mu$ ) but very wide (up to  $10\ \mu$ ) verrucate processes; it is free of this ornamentation only in a small area of the proximal face, near the trilete mark; wall distinct,  $3\text{--}6\ \mu$  thick. Trilete mark extends over one-half radius; usually closed but may be open, producing an irregular gap. Size range (fifteen specimens)  $84\text{--}116\ \mu$ .

*Holotype.* Plate 105, fig. 6;  $93 \times 70\ \mu$ ; slide LKC-10 (7-8) 2, 34-6 113-2.

*Remarks.* Although this species was rarely counted, it was observed more regularly in zones of the *Thymospora pseudothiesseni* assemblage.

Genus VERRUCOSISPORITES Ibr. emend. Smith *et al.* 1964

*Verrucosisporites compactus* sp. nov.

Plate 105, fig. 8

*Diagnosis.* Trilete spores; elliptical in both polar and equatorial views. Trilete mark extends from between one-half to two-thirds radius, frequently torn open to form an irregular gap; in some specimens, when not open, obscured by ornamentation; lips very thin and only slightly turned up. Exine covered with relatively large (to  $3\ \mu$  in width) but low, rounded verrucae with only slightly flattened apices; verrucae closely distributed throughout surface, slightly higher than  $1\ \mu$ . Size range (nine specimens)  $45\text{--}53\ \mu$ .

*Holotype.* Plate 105, fig. 8;  $48 \times 37\ \mu$ ; slide LKC-12 (5-6) 1, 25-1 129-5.

*Remarks.* This species was never counted. It differs from the other species of *Verrucosisporites* by its small size and relatively large verrucae.

Subinfraturma NODATI Dyb. and Jach. 1957  
Genus LOPHOTRILETES Naum. ex Pot. and Kr. 1954

*Lophotriletes interruptus* sp. nov.

Plate 105, fig. 12

*Diagnosis.* Trilete spores; triangular in polar view with round to semicircular radial corners and gently to strongly concave inter-radial margins. Exine approximately one micron thick, covered by relatively large (about  $3\ \mu$  by  $3\ \mu$ ) pointed to rounded conic. Trilete mark extends almost to the margin, usually closed and with thin lips. Size range (ten specimens) 28–38  $\mu$ .

*Holotype.* Plate 105, fig. 12;  $28 \times 28\ \mu$ ; slide LKC-4 (18–19) 1, 26·2 116·3.

*Remarks.* This species was very rarely encountered.

Genus PLANISPORITES Knox emend. Pot. and Kr. 1954

*Planisporites?* sp. A

Plate 105, fig. 9

*Description.* Trilete spore; roundly triangular, with broadly rounded radial corners and gently convex inter-radial margins. Exine slightly more than  $1\ \mu$  thick, covered over its surface by conic  $2\cdot5$ – $3\ \mu$  high and wide at their base; the conic number 42 at the margin. Trilete mark thin and very straight, extends almost to the margin; very thin but distinct raised lips attend the sutures. Arcuate thickenings in exine present in proximal hemisphere inter-radial and distinctly convex. Specimen  $75 \times 73\ \mu$ .

*Remarks.* The single specimen is very similar to *P. granifer*, differing only in the presence of the arcuate thickenings.

EXPLANATION OF PLATE 105

All figures  $\times 500$ .

Fig. 1. *Punctatisporites ellipticus* sp. nov., holotype.

Figs. 2–3, 5. *Granisporites medius* Dyb. and Jach. 2, trilete mark present, although indistinct. 3, Two sutures torn, the third indistinct. 5, Tetrad.

Figs. 4, 7. *Converrucosisporites pseudovalvus* sp. nov. 4, Holotype. 7, Verrucae tend to be concentrically oriented.

Fig. 6. *Schopfites grossus* sp. nov., holotype.

Fig. 8. *Verrucosisporites compactus* sp. nov., holotype.

Fig. 9. *Planisporites?* sp. A; note presence of arcuate ridges.

Figs. 10–11. *Acanthotriletes dimorphus* sp. nov. 10, Holotype; processes mostly blunted. 11, specimen with mostly spinose ornamentation.

Fig. 12. *Lophotriletes interruptus* sp. nov., holotype.

Figs. 13–14. *Acanthotriletes flexuus* sp. nov. 13, holotype.

Fig. 15. *Acanthotriletes tenuis* sp. nov., holotype.

Figs. 16, 20. *Knoxisporites* sp. A. 16, Paired ridges distinct.

Figs. 17–18. *Spackmanites ellipticus* gen. et sp. nov. 17, holotype. 18, Rudimentary trilete mark can be seen.

Fig. 19. *Spackmanites facierugosus* (Loose) comb. nov.

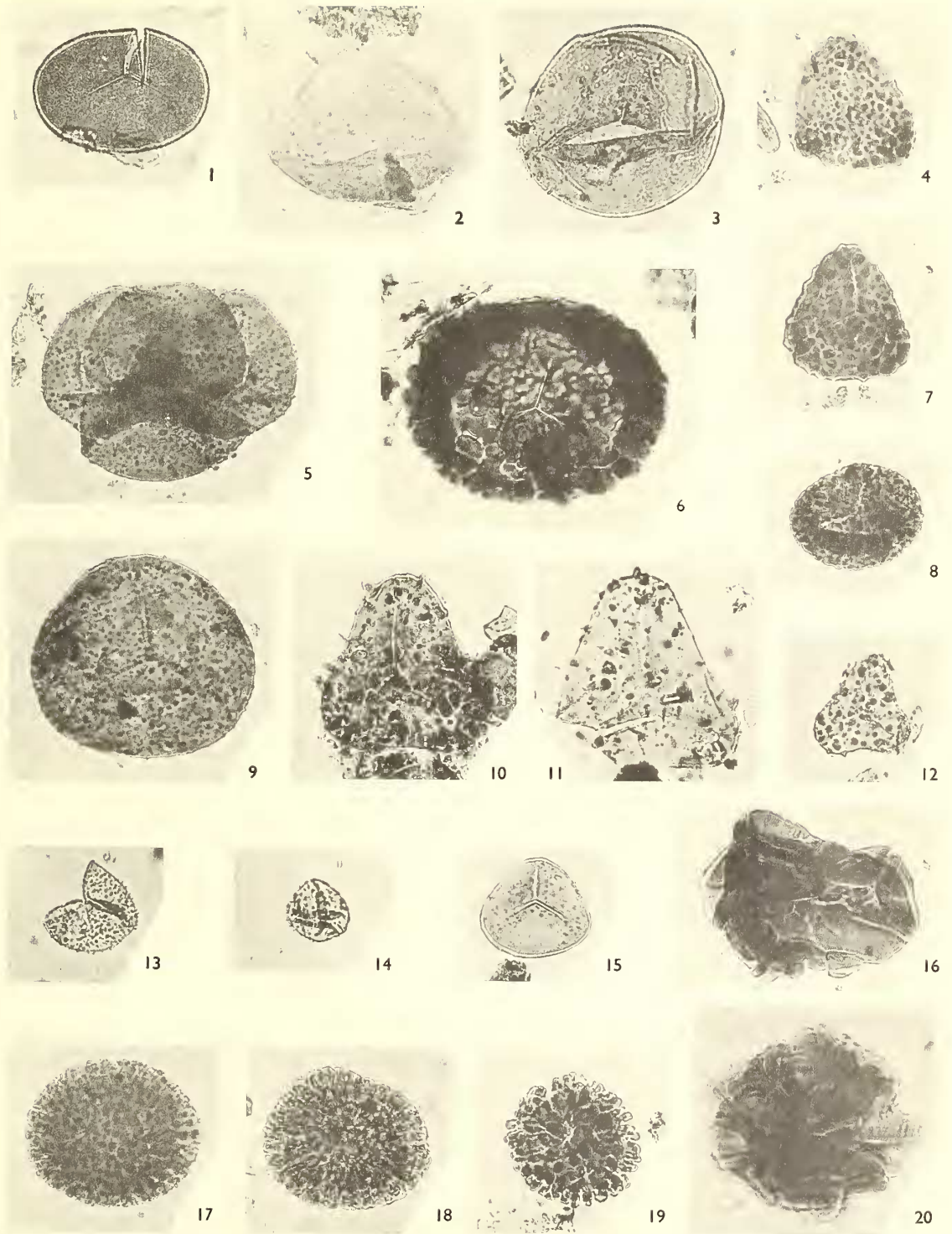












HABIB, Pennsylvanian miospores



## Genus ACANTHOTRILETES Naum. ex Pot. and Kr. 1954

*Acanthotriletes dimorphus* sp. nov.

Plate 105, figs. 10, 11

*Diagrams.* Trilete spores; roundly triangular, with broadly rounded radial corners and straight to gently concave (most often) or convex inter-radial margins. Exine 1–2  $\mu$  thick, covered with setaceous projections of essentially two types: (1) spine-like, broad-based (to 2  $\mu$ ) projections which taper rapidly to a sharp point, (2) rod-like projections, about 1.5 or 2  $\mu$  wide, with rounded or flattened distal ends. Ornamentation usually evenly distributed, with up to 25 projections from the outline; ratio of blunted to spinose projections varies from 1:3 to 3:1. Trilete mark extends more than two-thirds radius; frequently open with upturned lips, occasionally torn. Size range (twenty specimens) 48–65  $\mu$ .

*Holotype.* Plate 105, fig. 10; 58  $\times$  57  $\mu$ ; slide LKC–10 (8–9), wax mount 15.

*Remarks.* The species is irregularly distributed in the seam although it was found more often in zones containing the *Thymospora pseudothiesseni* and *Lycospora-Guthoerli-sporites erectus* assemblages.

*Acanthotriletes flexuus* sp. nov.

Plate 105, figs. 13, 14

*Description:* Trilete spores; triangular in outline. Exine less than 1  $\mu$  thick, covered with evenly distributed closely packed sharp spines up to 3  $\mu$  high; because of the thinness, the exine is almost invariably torn and/or folded. Trilete mark distinct, extends over two-thirds radius, it is attended by very dark thin folds. Size range (eight specimens) 22–32  $\mu$ .

*Holotype.* Plate 105, fig. 13; 30  $\times$  28  $\mu$ ; slide LKC–2 (8–9), 33.6 110.4.

*Acanthotriletes tenuis* sp. nov.

Plate 105, fig. 15

*Diagnosis.* Trilete spores; roundly triangular in polar view, with rounded radial corners and straight to convex inter-radial margins. Exine about 1–2  $\mu$  thick, sparsely covered by slender, gently tapering spines, never exceeding a height twice their width, and up to 4  $\mu$  high; about 15 to 20 spines are present at the outline, although in a few specimens only 8 or 9; the spines tend to group inter-radially at the equator, although they are also present at the radial corners. Trilete mark distinct, extends at least two-thirds radius; lips very thin and ill-defined. Size range (fifteen specimens) 33–41  $\mu$ .

*Holotype.* Plate 105, fig. 15; 33  $\times$  33  $\mu$ ; slide LKC–12 (8–9) 1, 28.5 126.7.

*Remarks.* The species was observed from only three localities. It is distinguished mainly by its very sparse, small, gently tapering spines.

## Subinfraturma BACULATI Dyb. and Jach. 1957

## Genus SPACKMANITES gen. nov.

*Type species.* *S. ellipticus* sp. nov.

*Diagnosis.* Trilete spores; overall outline circular to elliptical. Spore body almost completely obscured by the presence of long, very closely packed rod-shaped or club-shaped baculate processes, each of which is near-straight sided and approximately twice as long as wide; no appreciable thickening of the bacula occurs at the bases; they are evenly distributed over the entire surface of the exine, so much so that they are almost always appressed to one another at the bases; in most cases the bacula are partially fused, either at the base or at the distal ends; bacula usually rounded at the apices, or flat, with indentations. Trilete mark usually short, or may even be represented only by a triangular gap in the exine; usually can be seen only with careful focusing. Size range 30–70  $\mu$ .

*Remarks.* *Spackmanites* is characterized by closely spaced, long bacula which are tightly appressed to each other and even partially fused, the effect of which is to obscure the outline of the spore body. The genus most closely resembles *Verrucosisorites* and *Raistrickia*; it differs from the former in the lack of verrucae, and from the latter in the tight packing and partial fusing of the bacula.

*Spackmanites ellipticus* sp. nov.

Plate 105, figs. 17, 18

*Diagnosis.* Trilete spores; distinctly elliptical to oval in outline. Exine profusely covered with rod-like bacula which in some cases fuse with each other near their bases; bacula typically smoothly truncated or slightly indented at their distal terminations; many bacula thicken distally, appearing club-shaped in profile. Trilete mark short, with sutures of unequal lengths; frequently torn to form an irregular triangular gap. Size range (twenty specimens) 50–67  $\mu$ ; exclusive of ornamentation, 34–49  $\mu$ .

*Holotype.* Plate 105, fig. 17; 60  $\times$  51  $\mu$  (42  $\times$  36  $\mu$ ); slide LKC-12 (63–64), wax mount 39.

*Remarks.* The truncated and slightly indented bacula, which are partially fused, distinguish this species. It rarely exceeded one per cent in any zone, being found most frequently in those containing the *Lycospora-Guthoerlisporites erectus* assemblage.

*Spackmanites facierugosus* (Loose) comb. nov.

Plate 105, fig. 19

1934 *Reticulatisporites facierugosus* Loose, p. 155, pl. 7, fig. 26.

1954 *Verrucosisorites facierugosus* (Loose); Butterworth and Williams, p. 754, pl. 18, fig. 6, text-fig. 1, 3.

*Remarks.* An excellent description of the species is given in Butterworth and Williams (1954, p. 754). Its more circular outline, less densely packed bacula with rounded apices, separates this species from *S. ellipticus*. *Spackmanites facierugosus* is usually restricted to samples of the *Lycospora-Guthoerlisporites erectus* assemblage. It was rarely counted.

Infraturma MURORNATI Pot. and Kr. 1954

Genus KNOXISPORITES Pot. and Kr. 1954

*Knoxisorites* sp. A

Plate 105, figs. 16, 20

*Description.* Trilete spores; outline distinctly polygonal. Exine characterized by thick

ridges, approximately  $3\ \mu$  wide, paired at polygonal corners but then separate, with each ridge continuing around the peripheral area; exine otherwise about  $2\ \mu$  thick, levigate. Two specimens described, measure about  $75\ \mu$ ; similar to *Knoxisporites cinctus* (Lub. and Waltz) Butt. and Will. but differ in size and opening out of paired ridges. Specimens were recovered from the *Lycospora-Guthoerlisporites erectus* assemblage zone at Station 7.

Turma ZONALES (Benn. and Kidst.) R. Pot. 1956  
 Subturma AURITOTRILETES Pot. and Kr. 1954  
 Infraturma AURICULATI (Schopf) Pot. and Kr. 1954  
 Genus TRIQUITRITES Wilson and Coe 1940

*Triquitrites cheilus* sp. nov.

Plate 106, figs. 1, 2

*Diagnosis.* Trilete spores; triangular in polar view, with gently to markedly concave inter-radial margins and rounded, extending radial corners. Trilete mark distinct and extends to just short of the corners; it is bordered by wide, thick, and darkened lips (to  $7\ \mu$  wide) which are raised. At the radial extremities round to flattened valvae are present, which tend to grade in transitionally towards the polar area. Inter-radial margin bordered by a relatively thin (to  $2\ \mu$  wide), sometimes indistinct, ridge which thickens radially into the valvae. Exine levigate, with tendency to become irregular; approximately  $2\ \mu$  thick. Size range (fifteen specimens)  $45\text{--}60\ \mu$ .

*Holotype.* Plate 106, fig. 1;  $53 \times 51\ \mu$ ; slide LKC-6 (1-2) 1, 40-6 124-3.

*Remarks.* The species is ubiquitously distributed, but rarely exceeds one per cent in any assemblage zone.

*Triquitrites magnificus* sp. nov.

Plate 106, fig. 3

*Diagnosis.* Trilete spores; isodiametric triangular in polar view. Trilete mark distinct and almost always open; extends almost to radial margins and attended by relatively wide (to  $5\ \mu$ ) lips that are slightly raised. Radial corners consist of flattened or stubby, thick valvae. Ornamentation of rather long digitated, somewhat sinuous baculate processes on an otherwise levigate exine. Projections, usually confined to areas of lips and valvae, about  $10\text{--}15\ \mu$  long and near straight-sided. Size range (seven specimens)  $58\text{--}78\ \mu$ .

*Holotype.* Plate 106, fig. 3;  $75 \times 78\ \mu$ ; slide LKC-13 (18-19) 1, 36-0 107-9.

*Remarks.* This rare species was never counted. *Triquitrites magnificus* sp. nov. differs from *T. cheilus* sp. nov. in the possession of baculate processes, and from other species of *Triquitrites* in the concentration of processes at the lips and valvae.

*Triquitrites* sp. A

Plate 106, fig. 4

*Description.* Trilete spore; triangular in polar view, with convex inter-radial margins and angular radial corners. Trilete mark extends almost to radial corners; lips well-defined,

slightly upturned. Radial corners thickened by rectangular to square-shaped valvae which grade in towards the polar area. Ornamentation of scattered lobed cristae, radially disposed; cristae low-lying, wider (to  $5\ \mu$ ) than high (to  $3\ \mu$ ), they are confined to distal and equatorial areas. Specimen  $75 \times 68\ \mu$ .

*Remarks.* *Triquitrites* sp. A resembles *T. crassus* Kos. but has its ornamentation restricted to the distal and equatorial areas of the exine.

Genus AHRENSISPORITES Pot. and Kr. 1954

*Ahrensia sporites vagus* sp. nov.

Plate 106, fig. 5

*Diagnosis.* Trilete spores; triangular in polar view, with rounded radial corners and gently concave to convex inter-radial margins. Kyrtocone best developed in inter-radial area and can always be traced to radial corners where, however, it is distinguished occasionally only with oil magnification; inner part raised inter-radially to form distinct thickening. Trilete mark distinct, extends approximately three-fourths radius; usually open, with thin lips. Exine smooth to minutely pitted. Size range (twenty specimens)  $38\text{--}55\ \mu$ .

*Holotype.* Plate 106, fig. 5;  $49 \times 41\ \mu$ ; slide LKC-12 (8-9), wax mount LK-10.

*Remarks.* This species is characterized by the indistinct development of the kyrtocone at the radial corners. It was commonly encountered in samples of the *Densosporites oblatum* and *Punctatisporites obliquus* assemblages, and rare elsewhere.

Subturma ZONOTRILETES Waltz 1935

Infraturma CINGULATI Pot. and Kr. 1954

Genus CRASSISPORIA Bhardwaj 1957

*Crassispora kosankei* (Pot. and Kr.) Bhardwaj

Plate 106, figs. 9-10, 13

*Remarks.* Some representatives of *Crassispora kosankei* observed in this study displayed a high degree of crassitudo development. The species was encountered in tetrads in rare instances. It is present at every locality, becoming most abundant in the upper portions of zones containing the *Lycospora-Guthoerlisporites erectus* assemblage.

Genus LYCOSPORA S. W. and B. 1944

*Lycospora contacta* sp. nov.

Plate 106, figs. 6, 8

*Diagnosis.* Trilete spores; roundly triangular to rounded in polar view and hemispherical in equatorial view. Exine approximately  $1\ \mu$  thick, covered over its surface by very small (probably less than  $1\ \mu$ ) rounded grana. Equatorial crassitudinous thickening,  $3\text{--}5\ \mu$  wide, grades irregularly towards polar area; indents most markedly at radial extension of trilete mark. Trilete mark distinct, straight, passes through indented



crassitudinous thickening to margin; lips thin but distinct, slightly upturned. Size range (twelve specimens) 30–35  $\mu$ .

*Holotype*. Plate 106, fig. 6; 32  $\times$  32  $\mu$ ; slide LKC-12 (36–37) 1, 31.8 124.4.

*Remarks*. The species was very rarely counted, but was observed most frequently in samples of the *Thymospora pseudothiesseni* and *Lycospora-Guthoerlisporites erectus* assemblages. *Lycospora contacta* sp. nov. is distinguished by the irregular thickening at the margin which extends towards the polar area at the radial corners.

#### Genus GRAVISPORITES Bhard. 1954

##### *Gravisporites densus* sp. nov.

Plate 106, fig. 11

*Diagnosis*. Trilete spores; subcircular to oval in polar view, but often triangular and even pentagonal due to folding around the rigid trilete mark. Trilete mark distinct and rigid because of thick, wide (to 5  $\mu$ ), elevated ridges. Exine usually folds around trilete mark; crassitudo distinct, to 4  $\mu$  wide, usually folded; exine 1–2  $\mu$  thick, irregularly surfaced with grana of various sizes. Size range (nine specimens) 45–55  $\mu$ .

*Holotype*. Plate 106, fig. 11; 53  $\times$  48  $\mu$ ; slide LKC-10 (30–31) 2, 39.6 122.6.

*Remarks*. The species was only very rarely encountered.

#### Genus ROTASPORA Schemel 1950

##### *Rotaspora? perforata* sp. nov.

Plate 106, fig. 7

*Diagnosis*. Trilete spores; roundly triangular in polar view; outline in some specimens accentuated by protrusion of trilete sutures. Cingulum smooth, but characterized by relatively large perforations aligned along its periphery, forming a peripheral rim. Central body slightly more rounded than cingulum, but still retains triangular outline; appears detached from cingulum, being connected solely by the sutures; ornamentation minutely punctate or scabrate. Trilete mark prominent; raised and extends to outer margin of cingulum. Size range (five specimens) 28–35  $\mu$ .

*Holotype*. Plate 106, fig. 7; 28  $\times$  26  $\mu$ ; slide LKC-7 (9–10) 1, 18.0 125.0.

*Remarks*. This species is distinguished by its distinctly perforated cingulum. It is only provisionally assigned to *Rotaspora* on the basis of the presence of a rim (?) at the outer margin of the cingulum. The actual occurrence of a rim is not firmly established, as it may be the result solely of the marginal alignment of perforations. Were this to be the case, the species would be better assigned to *Lycospora*.

#### Genus DENSOSPORITES Berry emend. S. W. and B.

##### *Densosporites oblatius* sp. nov.

Plate 106, figs. 12, 14

*Diagnosis*. Trilete (?) spores; oblate triangular in polar view, the radial corners rounded

but always retaining some angularity. Cingulum occupies from one-third to one-half the area of the proximal surface of the central body, appears bizonate, becoming appreciably darker at its inner margin; ornamented by radiating, prostrate spines up to  $5\ \mu$ ; spines taper to sharp point; they vary from one or two per specimen to over fifty; in overmacerated specimens, many spines destroyed, leaving radial pits in cingulum. Central body smooth to distinctly punctate; punctae, when they occur, restricted to proximal surface; verrucae, up to  $8\ \mu$  wide, on distal surface. No evidence of trilete mark. Size range (twenty-five specimens)  $57\text{--}70\ \mu$ .

*Holotype*. Plate 106, fig. 12;  $68 \times 66\ \mu$ ; slide LKC-10 (2-3) 1, 16 113-3.

*Remarks*. This species is very similar to *D. sphaerotriangularis* Kos., differing only in the presence of tapering prostrate spines and slightly larger size.

*Densosporites spackmanii* sp. nov.

Plate 106, figs. 15 a, b

*Diagnosis*. Trilete (?) spores; distinctly triangular in polar view, with a very irregular outline. Cingulum heavily sculptured by irregular flaps which appear imbricate; it is expressed on the outer margin by deeply cut crenulations, the outer portion of which forms a mammoid sculpture; it occupies approximately 30% or more of proximal area of central body. Central body more circular in outline; smooth to punctate on proximal surface, distal surface covered with 15 to 25 large verrucae. Distinct trilete mark lacking, although very faint trace can be seen on several specimens. Size range (nine specimens)  $48\text{--}63\ \mu$ .

*Holotype*. Plate 106, fig. 15;  $58 \times 61\ \mu$ ; slide LKC-10 (3-4) 3, 30-8 114-9.

*Remarks*. The heavily sculptured cingulum and distal verrucae distinguish this species. Only nine specimens were found. *Densosporites spackmanii* sp. nov. closely resembles

EXPLANATION OF PLATE 106

All figures  $\times 500$ .

Figs. 1-4. *Triquirites* spp. 1-2. *T. cheilus* sp. nov. 1, Holotype. 3, *T. magnificus* sp. nov., holotype. 4, *T.* sp. A. Distal focus; distinct cristae.

Fig. 5. *Ahrensia sporites vagus* sp. nov., holotype; ill-defined radial extensions of kyrtome.

Figs. 6, 8. *Lycospora contacta* sp. nov. 6, holotype; polar indentation of crassitudinous margin at radial corners well-expressed.

Fig. 7. *Rotaspora? perforata* sp. nov., holotype.

Figs. 9-10, 13. *Crassispora kosankei* (Pot. and Kr.) Bharad. Specimens possess very well-developed crassitudinous thickenings. 9, Polar view; triangular gap. 10, Equatorial view; well-developed crassitudo. 13, Tetrad; area of contact in each specimen, upper specimen in focus.

Fig. 11. *Gravisporites densus* sp. nov. holotype.

Figs. 12, 14. *Densosporites oblatum* sp. nov. 12, holotype; prostrate radiating spines and distal verrucae. 14, Verrucae slightly smaller.

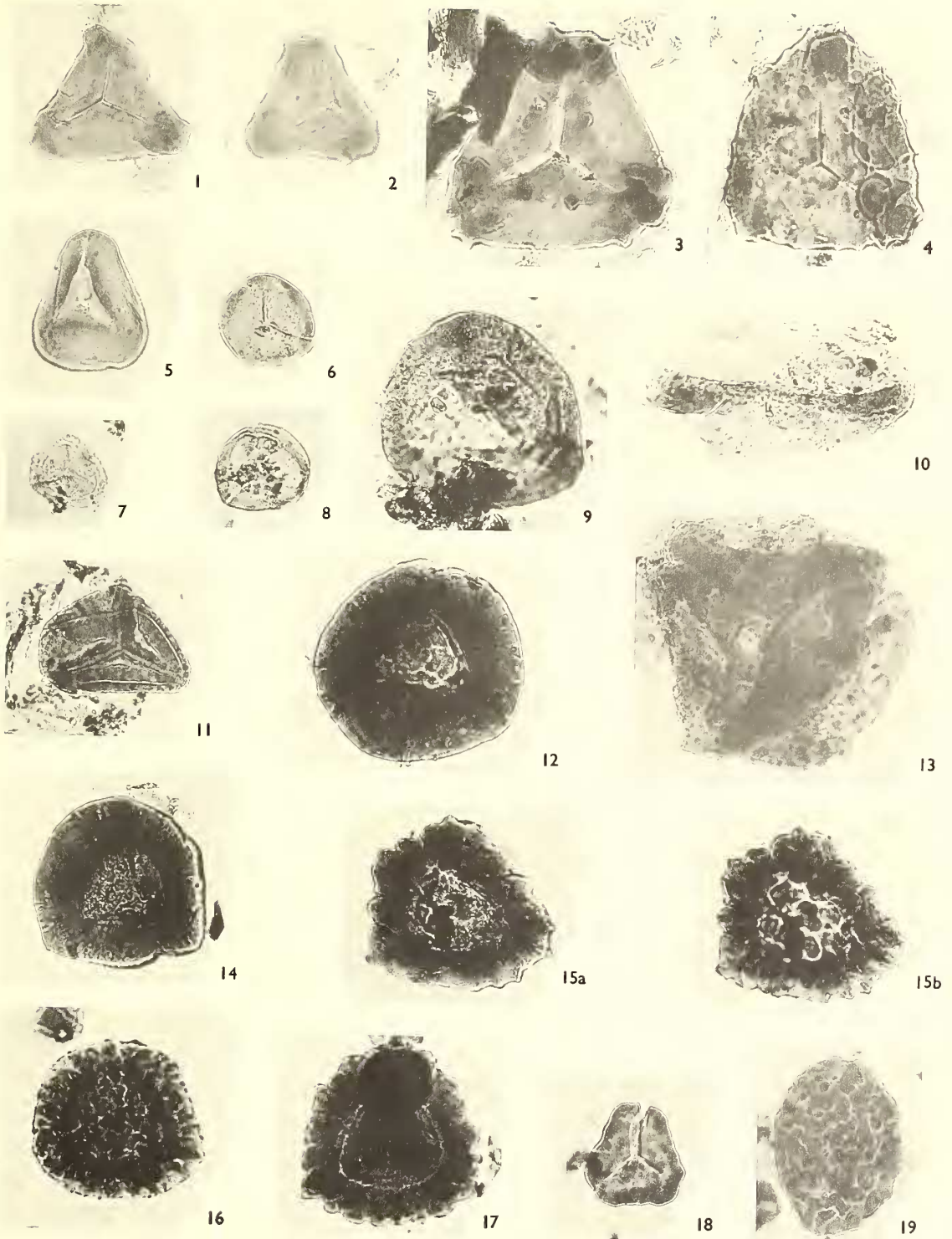
Fig. 15. *Densosporites spackmanii* sp. nov., holotype; a, Proximal focus, structured cingulum, and proximally punctate spore body. b, Distal focus, large verrucae.

Fig. 16. *Cristatisporites verrucosus* (Dyb. and Jach.) comb. nov.

Fig. 17. *Monilospora* sp. A; trilete very faint but extends almost to outer margin of spore.

Fig. 18. *Savitrisporites bluntus* sp. nov., holotype.

Fig. 19. *Thymospora concentrica* sp. nov., holotype.



HABIB, Pennsylvanian miospores



species of *Asperispora* Stapl. and Janson. It is provisionally placed in *Densosporites*, however, because of the distinct verrucae on the distal surface and lack of distinctive sutural ridges.

Genus CRISTATISPORITES Pot. and Kr. 1954

*Cristatisporites verrucosus* (Dyb. and Jach.) comb. nov.

Plate 106, fig. 16

1957 *Densosporites verrucosus* Dybova and Jachowicz, p. 166, pl. 50, figs. 1-4.

*Remarks.* The presence of radially aligned verrucae which are fused at their bases (Potonie and Kremp's 'kammen') warrants the inclusion of this species in *Cristatisporites*.

Genus MONILOSPORA Hacq. and Barss emend. Staplin 1960

*Mouilospora* sp. A

Plate 106, fig. 17

*Description.* Trilete spore; roundly triangular in polar view, with convex inter-radial margins and roundly angular radial corners. Capsula, where it projects beyond central body, from 13 to 19  $\mu$  wide; it is characterized by a strongly crenulated outer margin, giving the specimen a rather serrated overall outline; it is very thin (less than 1  $\mu$ ) where it encloses the proximal and distal hemispheres of the central body. Central body roundly triangular, with gently concave inter-radial margins; smooth, and approximately as thick (approx. 2  $\mu$ ) as the inner margin of the free portion of the capsula. Trilete mark indistinct, but easily seen with careful focusing; extends almost to outer margin of capsula. Specimen 66  $\times$  56  $\mu$ , central body 39  $\times$  38  $\mu$ .

*Remarks.* Single specimen from Station 1.

Genus SAVITRISPORITES Bhardwaj 1956

*Remarks.* Bhardwaj's diagnosis and schematic illustration (1956, pp. 127-8, text-fig. 3a, b) of *Savitrissporites* distinguish it as a patellate spore genus. It differs from other patellate genera described here in its slightly thickened angles (Bhardwaj, p. 127).

*Savitrissporites bluntus* sp. nov.

Plate 106, fig. 18.

*Diagnosis.* Trilete spores; isodiametric triangular in polar view, with slightly thickened, truncated or rectangular radial corners and straight to gently concave or convex inter-radial margins. Patella 3-6  $\mu$  wide at equator, characterized by a gently crenulated equatorial margin which extends on to the distal surface to form a reticulum in polar view with wide (approx. 3  $\mu$ ) but ill-defined muri and smaller lacunae. Proximal surface smooth. Trilete mark distinct, extends almost to inner margin of patella; usually open, with thin, raised lips. Size range (fifteen specimens) 30-38  $\mu$ .

*Holotype.* Plate 106, fig. 18; 37  $\times$  35  $\mu$ ; slide LKC-12 (7-8) 1, 24.2 118.9.

*Remarks.* This species is distinguished by its blunted isodiametric shape and small size. It was encountered most frequently in zones containing *Thymospora pseudothiessenii* and *Punctatisporites obliquus* assemblages.

Turma MONOLETES Ibr. 1933  
 Subturma AZONOMONOLETES Luber 1935  
 Infraturma SCULPTATOMONOLETI Dyb. and Jach. 1957  
 Genus TUBERCULATOSPORITES Imgrund 1952  
*Tuberculatosporites spinoplicatus* sp. nov.

Plate 107, figs. 1-3

*Diagnosis.* Monolete spores; roundly elliptical to bean-shaped in outline. Exine 1-2  $\mu$  thick, somewhat loosely covered with flimsy, usually curved, spinose projections which are best seen at the outline; from 10 to 20 of the processes present at the outline; each process characterized by from 2 to 5 small, radiating folds at its base; processes 2-10  $\mu$  long and vary in side view from almost straight-sided with a length of more than twice its width, to relatively short with tapering sides. Monolete mark distinct, almost always open, but may be folded along its entire length; extends almost the entire length of the spore body; lips thin, slightly raised. Size range (twelve specimens) 106-126  $\mu$ .

*Holotype.* Plate 107, fig. 1; 119  $\times$  81  $\mu$ ; slide LKC-1 (6-7), wax mount 31.

*Remarks.* The presence of radiating small folds at the base of spinose protrusions makes this species unique. Specimens corresponding to this species were observed also in samples from the Cherokee coals of southeastern Kansas.

Genus THYMOSPORA Wilson and Venkatachala 1964

*Thymospora concentrica* sp. nov.

Plate 106, fig. 19

*Diagnosis.* Monolete spores; elliptical outline. Exine relatively thick, over 2  $\mu$ ; ornamented throughout by thick, low-lying (approx. 3  $\mu$  high) verrucae which commonly fuse into sinuous, elongate vermiculae; in some specimens, the ornamentation is near-concentric. Monolete mark over two-thirds length of spore body; it is usually obscured by ornamentation, but can be observed with careful focusing. Size range (ten specimens) 60-90  $\mu$ .

*Holotype.* Plate 106, fig. 19; 61  $\times$  43  $\mu$ ; slide LKC-8 (24-25) 1, 29-9 117-1.

*Remarks.* This species is distinguished by its coarse ornamentation and large size.

INCERTAE SEDIS

Spore sp. A

Plate 107, fig. 4

*Description.* Trilete spore; oval in outline. Crassitudinous thickening at periphery, up to 7  $\mu$  wide. Exine otherwise approximately 1-2  $\mu$  thick, covered with very thin, curving, radially branching cristae, which are low-lying (approx. 1  $\mu$  high). Very short, irregular trilete mark is present, though indistinct; it is accentuated by a darkened contact area. A relatively large lenticular fold trends the length of the specimen. Size 58  $\times$  48  $\mu$ .

*Remarks.* The presence of a crassitudinous thickening relates this specimen to *Crassispora*.

## Spore sp. B

Plate 107, fig. 5 a, b

*Description.* Trilete spore; roundly elliptical in polar view. Exine approximately  $1\ \mu$  thick, covered with sparsely distributed clusters of small hemispherical grana, each cluster of 15 to 25 grana. Triangular-shaped opening, with flaps folded back, indicating a torn trilete mark. Size  $76 \times 66\ \mu$ .

*Remarks.* Specimen is characterized by its clustered grana, and is otherwise very similar to species of *Granisporites*.

## Spore sp. C

Plate 107, fig. 7 a, b

*Description.* Trilete spore; triangular in polar view, with near straight-sided inter-radial margins and sharply rounded radial corners. Exine approximately  $2.5\ \mu$  thick, and characterized by an irregularly serrated equatorial outline; surface irregular but apparently without a distinct ornamentation pattern. On the distal surface, three deep but thin grooves approximately  $23\ \mu$  long form an incomplete triangle. Width of specimen external to grooves about  $12\ \mu$ . Trilete mark distinct, slightly wavy, extends almost to the radial margins; lips developed but not prominent. Size  $48 \times 41\ \mu$ .

*Remarks.* Specimen appears to be unique in its possession of oriented grooves on the distal surface.

## Spore sp. D

Plate 107, fig. 6

*Description.* Trilete spore; roundly triangular, with convex inter-radial margins and broadly angular radial corners. Central body roundly triangular, generally smooth and very thin, probably, less than  $1\ \mu$ ; eight to ten large (to  $5\ \mu$  wide) papillate-type thickenings aggregated in proximal polar area. Covering entire central body, except for a torn gap on proximal side, is a capsulate (?) structure; it is covered over its entire surface with short, tapering spines, not over  $3\ \mu$  high; spines broad-based. Trilete mark extends, on the outer structure, almost to the outer margin of the specimen. Size  $51 \times 51\ \mu$ , central body  $35 \times 35\ \mu$ .

*Remarks.* The presence of a capsulate-like thickening relates this specimen closely to *Monilospora*.

Anteturma POLLENITES R. Pot. 1931

Turma SACCITES Erdtman 1947

Subturma MONOSACCITES (Chitaley) Pot. and Kr. 1954

Infraturma TRILETESACCITI Leschik 1955

Subinfraturma INTRORNATI Butt. and Will. 1958

Genus GUTHOERLISPORITES Bhardwaj 1954

*Guthoerlisporites erectus* sp. nov.

Plate 107, fig. 8

*Diagnosis.* Monosaccate, trilete pollen grains; overall outline oval to elliptical in proximo-distal and oblique orientations. Central body circular to subcircular, probably

less than 1  $\mu$  thick, with a smooth surface; numerous slender folds concentrically disposed about periphery; outline vague. Saccus covers most of proximal surface of central body, thereby leaving only a somewhat indistinct outline of the latter structure; externally levigate and internally moderately reticulate; a darkening of the peripheral region occurs on most specimens. Trilete mark confined to area of central body, thin but straight and distinct; it extends from about one-half the distance to the margin to almost touching it; folds commonly continue the trace of the sutures, to the outline of the central body; lips very thin. Size range (thirty specimens) 60–89  $\mu$ ; central body 38–43  $\mu$ .

*Holotype*. Plate 107, fig. 8; 81  $\times$  69  $\mu$ ; slide LKC-11 (24–25) 2, 21.2 115.2.

*Remarks*. This species is distinguished from *Guthoerlisporites magnificus*, the type species, by its smaller size, and tendency of folds to continue the sutures of the trilete mark to the wall of the central body.

*Guthoerlisporites delicatus* (Kos.) comb. nov.

Plate 107, fig. 9

1950 *Wilsonia delicata* Kosanke 1950, pp. 54–55, pl. 14, fig. 4.

1959 *Wilsonites delicatus* (Kos.); Kosanke, p. 700.

*Remarks*. Kosanke (1950, p. 54) distinguished *Wilsonites* partly by its vaguely defined central body being either completely covered or largely covered by the saccus. His illustration of the holotype of this species, as well as all the specimens of it encountered in this study, shows a rather distinct central body. Acknowledging that *Wilsonites* and *Guthoerlisporites* are closely related genera, this species is placed in *Guthoerlisporites* on the basis of its distinct central body.

Subinfraturma EXTRORNATI Butt. and Will. 1958

Genus ENDOSPORITES Wils. and Coe 1940

*Endosporites globiformis* (Ibr.) S. W. and B.

Plate 107, fig. 10

1932 *Sporonites globiformis* Ibrahim, p. 447, pl. 14, fig. 5.

1944 *Endosporites globiformis* (Ibr.) Schopf, Wilson, and Bentall, p. 45.

1940 *Endosporites ornatus* Wilson and Coe, p. 184, fig. 2.

All figures  $\times$  500.

EXPLANATION OF PLATE 107

Figs. 1–3. *Tuberculatosporites spinoplicatus* sp. nov. 1, holotype. 2, specimen with somewhat angular outline, due to ornamentation; well-developed radiating folds at bases of spines. 3, three distinct folds radiate from base of a spine.

Figs. 4–7. Unnamed spores. 4, sp. A; contact area present, although ill-defined. 5, sp. B; *a*, Distal focus; clusters of grana. *b*, Proximal focus; triangular gap. 6, sp. C. 7, sp. D; *a*, Proximal focus; slightly undulating trilete mark; *b*, Distal focus, triangularly oriented grooves prominent.

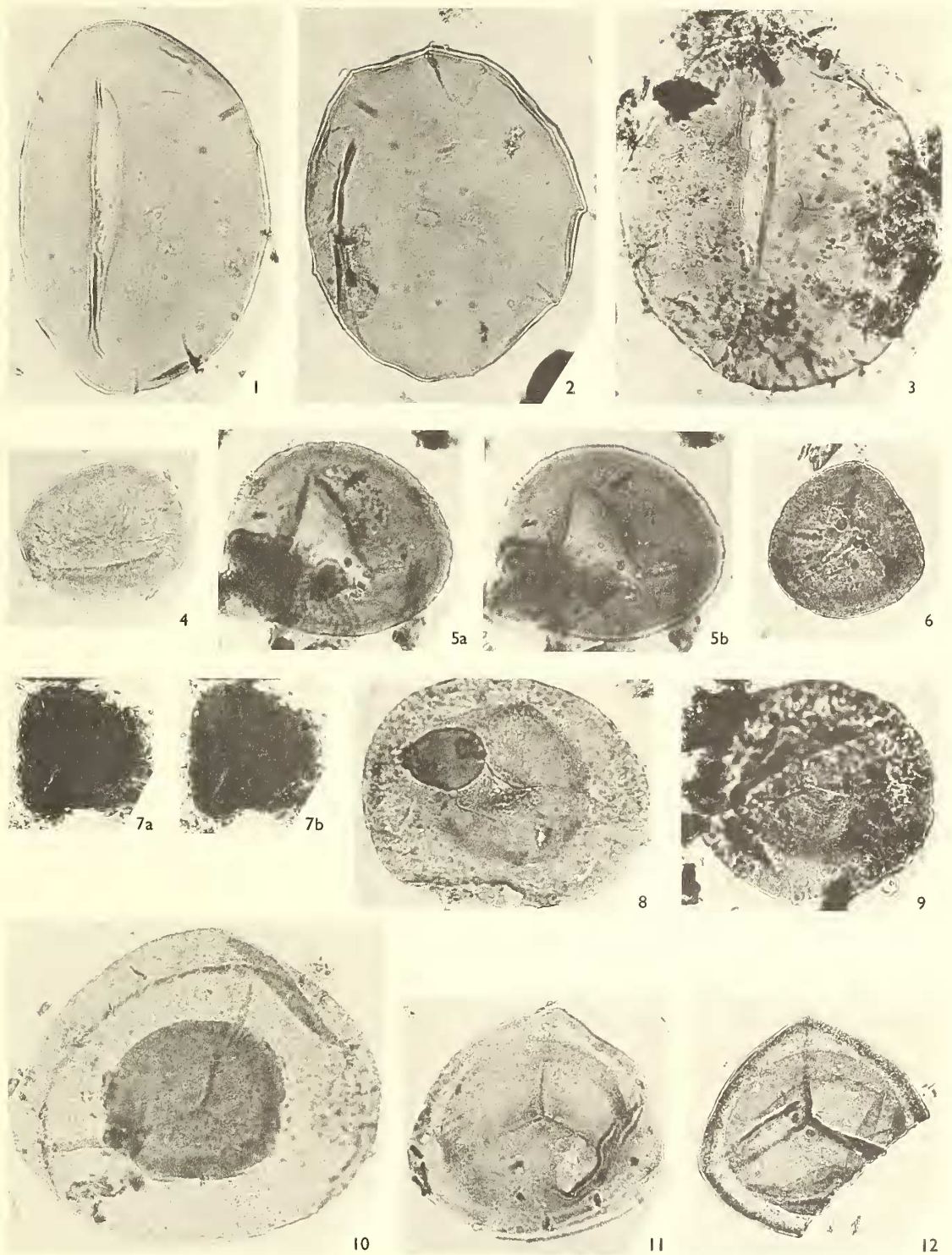
Fig. 8. *Guthoerlisporites erectus* sp. nov. holotype.

Fig. 9. *Guthoerlisporites delicatus* (Kos.) comb. nov.

Fig. 10. *Endosporites globiformis* (Ibr.) S. W. and B.

Figs. 11–12. *Endosporites grandicarpus* sp. nov. 11, holotype. 12, distinct apical papillae.





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*Remarks.* *Endosporites ornatus* is here considered a junior synonym of *E. globiformis*, primarily on the basis of Chaloner's (1958) description of the microspores in the lycopod cone species *Polysporia mirabilis*. Although specimens of both species of *Sporae dispersae* could morphologically be distinguished, they invariably occurred in the same samples, and gradational specimens were observed.

*Endosporites grandicorpus* sp. nov.

Plate 107, figs. 11, 12

*Diagnosis.* Monosaccate trilete spores; overall outline roundly triangular in polar view, with distinctly angular radial corners. Central body circular to sub-circular; it occupies most of the area of the specimens, extending seven-tenths the radius or more; less than  $1\ \mu$  thick; very commonly a number of small, lenticular folds criss-cross its distal hemisphere. Saccus sharply and densely punctate, showing best at the periphery; a distinct limbate thickening occurs at the periphery, approximately  $3\text{--}4\ \mu$  wide, attached to central body on proximal side. Trilete mark distinct, extends to margin of saccus. Apical papillae located inter-radially on proximal side, a phenomenon common in lycopod microspores. Size range (seven specimens)  $65\text{--}81\ \mu$ ; central body  $60\text{--}73\ \mu$ .

*Holotype.* Plate 107, fig. 11;  $80 \times 72\ \mu$ ; slide LKC-7 (9-10), wax mount 36.

*Remarks.* This species is distinguished by its relatively large central body, oblate triangular outline, and strongly differentiated limbus. It occurs most frequently in zones containing the *Thymospora pseudothiesseni* assemblage.

Infraturma VESICULOMONORADITI (Pant) Bhardwaj 1956

Genus PALEOSPORA gen. nov.

*Type species.* *Paleospora fragila* sp. nov.

*Diagnosis.* Elliptical to subcircular monosaccate grain with a longitudinal slit. Central body elliptical to circular and occupies an area about one-half or more of the enclosing saccus; in some cases it carries long, thin, concentric folds. Saccus thin, less distinctive than central body and very commonly folded or torn. A longitudinal fissure extends from over one-half to the complete length of the saccus; it forms a line along which entire specimens are commonly folded. An equatorial enclosing flange is the most prominent structure, and appears to hold the shape of the flimsy specimens; it is relatively wider than the saccus. The single described species ranges upward in size from 150 microns.

*Remarks.* This genus is distinguished from *Potonieisporites* by its distinct flange, and from *Spencerisporites* by its longitudinal fissure.

*Paleospora fragila* sp. nov.

Plate 108, figs. 1, 2

*Diagnosis.* Monosaccate spores or pollen with a straight longitudinal fissure confined to the area of the saccus; elliptical in outline. Central body more roundly elliptical,  $1\ \mu$  or less thick; it is enclosed by a closely appressing saccus with which it conforms in

outline. Both saccus and central body appear very flimsy and are almost always folded in several directions; they both appear to be essentially unornamented. Flange in an equatorial zonate structure of about the same thickness (approx.  $1\ \mu$ ) throughout its width; it is the most prominent and most highly ornamented structure; the ornamentation consists of very low-lying (approx.  $1\ \mu$  or less high) irregularly radiating corrugations or cristae, which become more distinctive toward the outer margin. Longitudinal fissure open in all observed specimens, ranging from a thin slit to a wide gap which participates in folds which, when they occur, run the entire length of the body. Size range (twenty-five specimens) 150–195  $\mu$ ; saccus 105–140  $\mu$ ; flange width 15–25  $\mu$ .

*Holotype*. Plate 108, fig. 1;  $161 \times 93\ \mu$ ; slide LKC-2 (21–22) 2, 36.5 115.2.

*Remarks*. This species does not appear to be restricted to any particular assemblage zone.

Genus POTONIEISPORITES Bhardwaj 1954

*Potonieisporites elegans* (Wils. and Kos.) emend.

Plate 108, fig. 3

1944 *Florinites elegans* Wilson and Kosanke, p. 330, fig. 3.

1964 *Potonieisporites elegans* (Wils. and Kos.); Wilson and Venkatachala, pp. 67–68.

*Emended diagnosis*. Monosaccate pollen grains; roundly elliptical in overall outline. Central body distinct, elliptical to circular in outline, characterized by prominent crescentic or lenticular folds which commonly transect each other, though on opposite sides of the central body, at angles approaching ninety degrees; the transverse folds, always two, appear confined to the distal hemisphere at or near the juncture of central body and saccus; the longitudinal folds, also two, are present on the proximal (free) hemisphere of the central body and trend along the maximum dimension of the body; ornamentation minutely punctate to granulose. Saccus externally levigate and internally moderately infra-reticulate, attached to central body only on its distal side. Tetrad mark prominent on proximal (free) side of saccus; it is essentially straight longitudinal, but occasionally T-shaped with a much reduced third suture, or even symmetrically (Y-shape) trilete.

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EXPLANATION OF PLATE 108

All figures  $\times 500$ .

Figs. 1–2. *Paleospora fragila* gen. et sp. nov. 1, holotype.

Fig. 3. *Potonieisporites elegans* Wils. and Kos. emend. Monolete mark continued across saccus by folds, optically superimposed on distally attached central body.

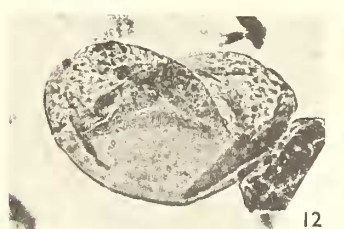
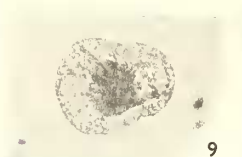
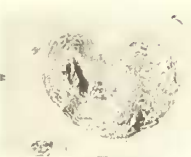
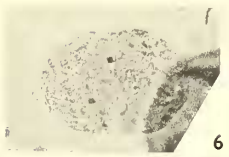
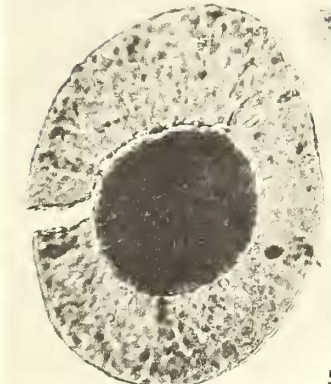
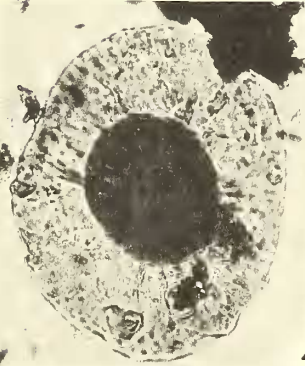
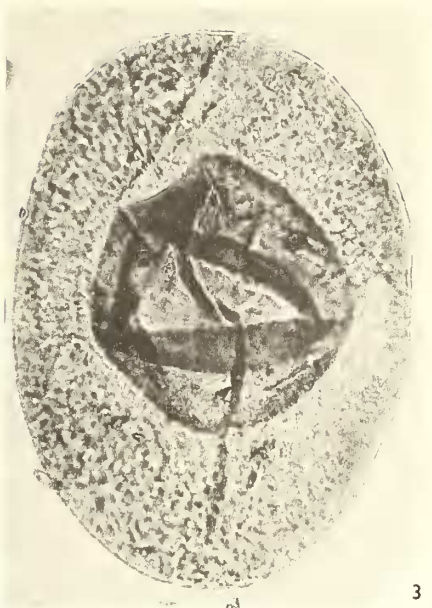
Figs. 4–5. *Florinites occultus* sp. nov. 4, holotype; irregular gap at contact of central body and distal surface of saccus, and radiating folds. 5a, Distal focus, showing contact of central body and saccus; saccus torn around thick central body. 5b, Proximal focus, showing rudimentary trilete mark on saccus.

Figs. 6–8. *Vesicaspora wilsonii* Schemel. 6, Polar view, showing vague central body. 7, Oblique view; continuation of saccus across central body illustrated by folds. 8, Equatorial view, showing orientation of saccus, proximally protruding central body, and tenuitas-like membrane crossing saccus distally.

Fig. 9. *Vesicaspora saarensis* (Bharad.) comb. nov.

Fig. 10. *Complexisporites chaloneriei* sp. nov. Holotype.

Figs. 11–12. *Pityosporites kittanningensis* sp. nov. 11, holotype.



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